Claims

1. A rheometer for determining a rheological property of a sample, comprising:

a driver for applying an alternating movement to a surface of the sample for causing an alternating movement of the sample;

a force measuring device for providing a force signal indicative of the reaction force exerted by the sample on the driver;

a displacement measuring device for providing a signal indicative of the alternating movement of the sample;

a processor for receiving the force signal and the movement signal to determine the rheological property of the sample; and

a signal generator for supplying to the driver a frequency sweep signal having a monotonic group delay function to cause the driver to supply the alternating movement of the sample.

2. The rheometer of claim 1 wherein the frequency sweep signal has a monotonic group delay function with a maximum value less than the acquisition period.

3. The rheometer of claim 2 wherein the frequency sweep signal has small crest factors and most preferably, close to 3dB if using a flat amplitude envelope in the time domain.

4. The rheometer of claim 1 wherein the driver includes a driver having terfenite material and means for supplying an electromagnetic force to the terfenite material to produce the alternating movement.

5. The rheometer of claim 1 wherein the apparatus includes a sample support comprised of a top plate and a

bottom plate which define a space for receiving the sample.

6. The rheometer of claim 1 wherein the displacement measuring device comprises a displacement transducer.

7. The rheometer of claim 1 wherein the force measuring device comprises a load cell.

8. The rheometer of claim 1 wherein the processor includes an analogue to digital converter for converting the signal from the load cell to a digital signal, and an analogue to digital converter for converting the signal from the displacement measuring means to a digital signal.

9. The rheometer of claim 8 wherein the processor is for determining the fourier transform of both the force signal and the movement signal, and the ratio of the fourier transform of the force signal $F(\omega)$ to the fourier transform of the movement signal $H(\omega)$.

10. The rheometer of claim 5 wherein at least one of the top plate and bottom plate is circular and has a radius a and the plates are separated by an average distance h and the property which is calculated is the complex modulus

$$G^{*}(\omega) = h^3/3\pi a^4 \times F(\omega)/H(\omega).$$

11. The rheometer of claim 1 wherein the signal generator is for supplying the frequency sweep signal which is ramped up at commencement of the signal and ramped down at cessation of the signal.

12. The rheometer of claim 11 wherein the signal is ramped up to full scale by a ramp function given by $\sin^2(\pi \times i/2n)$ and ramped down by a ramp function given by $\cos^2(\pi$

x i/2n) where there are n items in the signal and i indexes a particular item.

13. The rheometer of claim 12 wherein the ramping up of the signal and ramping down of the signal is performed by multiplying the signal for one signal period to respectively grow the signal from zero and then to attenuate the signal back to zero.

14. A method of determining a rheological property of a sample, comprising:

applying by a driver an alternating movement to a surface of the sample for causing an alternating movement of the sample;

measuring a force signal indicative of a reaction force exerted by the sample;

measuring a signal indicative of the alternating movement of the sample;

processing the force signal and the movement signal to determine the rheological property of the sample; and

supplying to the driver a frequency sweep signal having a monotonic group delay function to produce the alternating movement of the sample.

15. The method of claim 14 wherein the frequency sweep signal has a monotonic group delay function with a maximum value less than the acquisition period.

16. The method of claim 15 wherein the frequency sweep signal has small crest factors and most preferably, close to 3dB if using a flat amplitude envelope in the time domain.

17. The method of claim 14 wherein the vibrating means includes a driver including terfenite material and means for supplying an electromagnetic force to the

terfenite to produce the alternating movement.

18. The method of claim 14 wherein the method includes supporting the sample between a top plate and a bottom plate which define a space for receiving the sample.

19. The method of claim 14 wherein the displacement is measured by a displacement transducer.

20. The method of claim 14 wherein the force is measured by a load cell.

21. The method of claim 14 wherein the processing includes converting the force signal to a digital signal, and converting the displacement signal to a digital signal.

22. The method of claim 14 wherein the processor further includes determining the fourier transform of both the force signal and the movement signal, and the ratio of the fourier transform of the force signal to the fourier transform of the movement signal.

23. The method of claim 18 wherein at least one of the top plate and bottom plate is circular and has a radius a and the plates are separated by an average distance h and the property which is calculated is the complex modulus

$$G^*(\omega) = h^3/3\pi a^4 \times F(\omega)/H(\omega).$$

24. The method of claim 14 wherein the frequency sweep signal which is ramped up at commencement of the signal and ramped down at cessation of the signal.

25. The method of claim 24 wherein the signal is

ramped up to full scale by a ramp function given by $\sin^2(\pi \times i/2n)$ and ramped down by a ramp function given by $\cos^2(\pi \times i/2n)$ where there are n items in the signal and i indexes a particular item.

26. The method of claim 25 wherein the ramping up of the signal and ramping down of the signal is performed by multiplying the signal for one signal period to respectively grow the signal from zero and then to attenuate the signal back to zero.

27. A rheometer for determining a rheological property of a fluid sample, comprising:

a driver for applying an alternating movement to a surface of the sample for causing an alternating movement of the sample;

force measuring device for providing a force signal indicative of the reaction force exerted by the sample on the driver;

displacement measuring device for providing a signal indicative of the alternating movement of the sample;

processor for receiving the force signal and the movement signal to determine the rheological property of the sample; and

sample support having a top plate and a bottom plate between which a space is provided for receiving the sample, one of said plates being moveable relative to the other plate by the vibrating means, said one of said plates having a side edge, means for causing the fluid sample to extend up the side wall of the said one of the plates to form a concave meniscus so that upon movement of the said one of the plates, the meniscus will slip on the edge of the top plate thereby reducing the spring nature of the meniscus to reduce errors in the resulting measurement due to the spring nature of the meniscus.

28. The rheometer of claim 27 wherein the said support comprises a quartz surface on the at least said one plate at least in the vicinity of the meniscus so that the fluid flows up the said side surface thereby creating the meniscus which extends up the side surface of the said one plate.

29. The rheometer of claim 28 wherein the said at least one plate is formed from steel and the quartz surface is formed by vacuum depositing quartz onto the said steel plate.

30. The rheometer of claim 29 wherein the quartz surface has a thickness of about 100 micrometers.

31. The rheometer of claim 30 wherein both the top plate and the bottom plate are provided with the quartz surface having the thickness of about 100 micrometers.

32. The rheometer of claim 31 wherein the said one of the plates comprises the top plate.

33. A method of determining a rheological property of a sample fluid, comprising:

applying an alternating movement to a surface of the sample for causing an alternating movement of the sample;

measuring a force signal indicative of the reaction force exerted by the sample on the vibrating means;

measuring a signal indicative of the alternating movement of the sample;

processing the force signal and the movement signal to determine the rheological property of the sample; and

supporting the sample between a top plate and a bottom plate between which a space is provided for

receiving the sample fluid, one of said plates being moveable relative to the other plate by the vibrating means, said one of said plates having a side edge, and causing the sample fluid to extend up the side wall of the said one of the plates to form a concave meniscus so that upon movement of the said one of the plates, the meniscus will slip on the edge of the top plate thereby reducing the spring nature of the meniscus to reduce errors in the resulting measurement due to the spring nature of the meniscus.

34. The method of claim 33 wherein the step of causing the sample fluid to extend up the side wall comprises providing said one plate with a quartz surface at least in the vicinity of the meniscus so that the fluid flows up the said side surface thereby creating the meniscus which extends up the side surface of the said one plate.

35. The method of claim 34 wherein the providing step comprises vacuum depositing quartz onto the said one plate.

36. The method of claim 35 wherein the quartz surface has a thickness of about 100 micrometers.

37. The method of claim 36 wherein both the top plate and the bottom plate are provided with the quartz surface having the thickness of about 100 micrometers.

38. The method of claim 37 wherein the said one of the plates comprises the top plate.

39. A method of determining a rheological property of a sample, comprising:

supporting the sample between a pair of support plates spaced apart by a predetermined distance;

applying an alternating movement to one of the support members to cause an alternating movement of the sample;

measuring a force signal indicative of a reaction force exerted by the sample;

measuring a signal indicative of the alternating movement of the sample;

processing the force signal and the movement signal to determine the rheological property of the sample;

controlling the temperature of the sample so that the rheological property can be determined at different sample temperatures; and

maintaining the distance between the support member substantially constant notwithstanding the change in temperature of the sample.

40. The method of claim 39 wherein the alternating movement is supplied by a driver and the method includes supplying to the driver a frequency sweep signal having a monotonic group delay function to produce the alternating movement of the sample.

41. The method of claim 40 wherein the driver is connected to one of the support members by a connecting member and the distance between the support member is maintained substantially constant by forming the connecting member from a material having low coefficient of thermal expansion.

42. The method of claim 41 wherein the connecting member is formed from metal sold under the trade name INVAR and preferably the support member is gold plated.

43. A rheometer for determining a rheological property of a sample, comprising:

a pair of support members for supporting the

sample therebetween, the support member being spaced apart by a predetermined distance when making measurements;

a connecting member connected to one of the support members;

a driver for applying an alternating movement to the connecting member and the said one of the support member so the movement is applied to a surface of the sample for causing an alternating movement of the sample;

force measuring device for providing a force signal indicative of the reaction force exerted by the sample of the driver;

displacement measuring device for providing a signal indicative of the alternating movement of the sample;

a processor for receiving the force signal and the movement signal to determine the rheological property of the sample;

a temperature controller for controlling the temperature of the sample; and

wherein the connecting member is formed from a material having a low coefficient of thermal expansion so that the change in temperature caused by the temperature control means does not alter the space between the support members.

44. The rheometer of claim 43 wherein the connecting member comprises a support rod.

45. The rheometer of claim 43 wherein the support members are plates and in some embodiments the support rod and the plates are formed from the material having low thermal coefficient of expansion.

46. The rheometer of claim 43 wherein the temperature controller is a peltier heater.

47. The rheometer of claim 43 wherein the temperature

controller comprises individual temperature controllers for heating both of the support members so heat is conducted from the support members into the sample.

48. A rheometer for determining a rheological property of a sample, comprising:

a driver for applying an alternating movement to a surface of the sample for causing an alternating movement of the sample;

a force measuring device for providing a force signal indicative of the reaction force exerted by the sample on the driver;

a displacement measuring device for providing a signal indicative of the alternating movement of the sample;

a processor for receiving the force signal and the movement signal to determine the rheological property of the sample; and

a signal generator for supplying to the driver a signal to cause the driver to apply the alternating movement to the surface of the sample, which signal is ramped up at commencement of the signal and ramped down at cessation of the signal to prevent arbitrary displacements of the sample which could damage structures of interest in the sample.

49. The rheometer of claim 48 wherein the signal is ramped up to full scale by a ramp function given by $\sin^2(\pi \times i/2n)$ and ramped down by a ramp function given by $\cos^2(\pi \times i/2n)$ where there are n items in the signal and i indexes a particular item.

50. The rheometer of claim 48 wherein the signal is a frequency sweep signal having a monotonic group delay function.

51. A method of determining a rheological property of

a sample, comprising:

applying by a driver an alternating movement to a surface of the sample for causing an alternating movement of the sample;

measuring a force signal indicative of a reaction force exerted by the sample;

measuring a signal indicative of the alternating movement of the sample;

processing the force signal and the movement signal to determine the rheological property of the sample; and

supplying to the driver a signal which is ramped up at commencement of the signal and ramped down at cessation of the signal to prevent arbitrary displacements of the sample that could inadvertently damage structures of interest in the sample.

52. The method of claim 51 wherein the signal is ramped up to full scale by a ramp function given by $\sin^2(\pi \times i/2n)$ and ramped down by a ramp function given by $\cos^2(\pi \times i/2n)$ where there are n items in the signal and i indexes a particular item.

53. The method of claim 52 wherein the signal is a frequency sweep signal having a monotonic group delay function to produce the alternating movement of the sample.